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Research Department Report

THE DEVELOPMENT OF THE SWITCHED-HORN RADIO-CAMERA SYSTEM

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Summary

Radio-cameras are now well established at outside broadcast events (OBs) but conventional circularly polarised antennas and electromechanical tracking systems still leave considerable room for improvement. A new radio-camera system is described which uses a cluster of six directional transmitting antennas, with each antenna pointing in a different direction. Test signals inserted into the video during the field blanking interval are transmitted through each antenna in turn, and are then analysed at the receiving base station to determine which horn is transmitting the best signal. The result of this analysis is used to select the best horn for the following frame of video, and the result is updated 25 times each second. Both the level of the received signal strength and the degree of multipath distortion are analysed to determine the best horn.

This Report describes the development of a prototype switched-horn system and also describes two field trials, one of which took place during a live programme transmission. The results of the trials showed that the switched-horn system suffers from far less multipath distortion than conventional omnidirectional circularly-polarised antennas, and does not have any of the drawbacks of electromechanical systems.

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1. INTRODUCTION

Single-operator radio-cameras are now widely used at outside broadcast (OB) events to obtain dramatic shots close to the action, without the problems of a trailing cable. Although primarily used for sports events, such as rugby, golf or athletics, they also have other applications such as on stage at pop concerts. The flexibility of cable-free operation complements the compact lightweight CCD cameras that are now available. However, wire-less operation can suffer from picture distortion caused by multipath propagation.

A previous Report[1] described research into radio-camera systems within the BBC and outlined an electronically switched-antenna system. This Report describes the new 'switched-horn' system[2] in detail. Fig. 1 shows the experimental radio-camera being tested at Wembley Stadium.

Fig. 1 - The switched-horn system being tested at Wembley.

2. THE PROBLEMS

The ideal single-operator radio-camera would offer all of the positive features of a cabled camera — a reliable link, talkback channel, reverse vision and remote racking, but with the mobility of a camcorder. Most of these features are already available but the reliability of the vision link still has considerable scope for improvement.

The main problem facing radio-camera users is that of multipath propagation. In a typical sports stadium the structure of the stadium itself and the ground around the camera are all potentially reflecting surfaces. Multipath propagation can cause severe picture distortion which renders the shots unusable. Several methods for dealing with the multipath problem have been tried with varying degrees of success, as described below.

3. THE EVOLUTION OF THE SINGLE-OPERATOR RADIO-CAMERA

A simple fixed antenna radio-camera must have an *omnidirectional* radiation pattern to ensure that the receiving dish can pick up the transmitted signal regardless of the way the camera operator turns. It therefore follows that the reflecting surfaces, such as the grandstand structure, are also illuminated, and that at the receiver, these reflections can combine with the signal from the direct path to generate multipath. The simplest type of omnidirectional antenna uses linear polarisation and can only provide around 10 - 20% coverage of a stadium. In practice, this severe limitation means that linearly polarised 'omnis' are not used with BBC radio-cameras.

One way around the multipath problem is to use circular polarisation (CP). CP antennas are available in either left-hand or right-hand polarisation, and have the advantage that when a surface reflects a circularly polarised wave it changes the sense of the polarisation. By designing the receiving antenna to pick up only one sense of polarisation — the type being transmitted — those signals radiating from the reflecting surfaces will be rejected, and so multipath distortion is thereby substantially reduced.

Unfortunately, it is impossible to design an omnidirectional CP antenna with 100% purity of

polarisation in all directions. Also, in practice, the reflecting surfaces do not completely reverse the sense of polarisation, and it is only the *odd* order reflections which are reversed.

However, the use of CP antennas has led to a dramatic improvement in the usefulness of radio-cameras, typically giving about 90% coverage of a stadium. Indeed, the success of Research Department's 2.5 GHz and 12 GHz omnidirectional CP antennas has given BBC Outside Broadcast Departments a very versatile mobile camera system which has seen extensive use at all types of OB. Nevertheless, the elusive 10% not covered will often be just where the producer wants to get his shots!

It should be realised that an omni-CP transmitting antenna *generates* as much multipath propagation as a simple linearly polarised omni-directional antenna, but in a CP system, the cross polar discrimination of the receiving antenna rejects the reflected signal with its opposite polarisation to that transmitted. However, rather than transmitting towards potentially reflecting surfaces and then trying to reject the resulting multipath, an alternative solution is to avoid generating the multipath in the first instance by using a directional transmitting antenna.

The simplest method of pointing a directional transmitting antenna is to use a two-man team, where the second operator carries the antenna and constantly points it towards the receiver. Having two operators produces a very reliable, if costly, link but it also reduces mobility, so is rarely used.

The action of the second operator can be emulated by an electromechanically steered directional antenna; such an experimental system was developed at Research Department in 1986. The steering of the antenna was controlled by a microcomputer at the receiver, which remotely panned the transmitting horn in order to maximise the signal level, and therefore home in on the direction of the receiving dish. This system used just a single vision link and a single narrow band audio channel to control the horn direction.

Another method, which has been investigated by others, is to use a gyroscope to maintain the direction of the antenna, irrespective of the direction in which the camera is pointing. Unfortunately, this is only effective if the camera is constrained to move radially with respect to the dish. Any other type of movement would produce an offset in the bearing of the antenna.

More recently, commercial manufacturers have produced a radio-camera system based on an electromechanically steered antenna — operating in two axes where the control system is located in the camera. These systems turn the antenna to home in on a beacon signal transmitted from the receive site. The beacon signal is in fact a reverse vision link, and this can assist the camera operator in monitoring the performance of the transmission. Unfortunately, because the transmitter and receiver use two different channels, there is uncertainty as to whether picture break-up seen by the camera operator on the return feed is caused by problems on the outgoing signal — the all-important contribution feed — or on the return link, which is only seen by the camera operator. Although a reverse video link is welcomed by camera operators, at a large OB with many radio-cameras the extra vision link can be a problem due to the limited availability of spectrum.

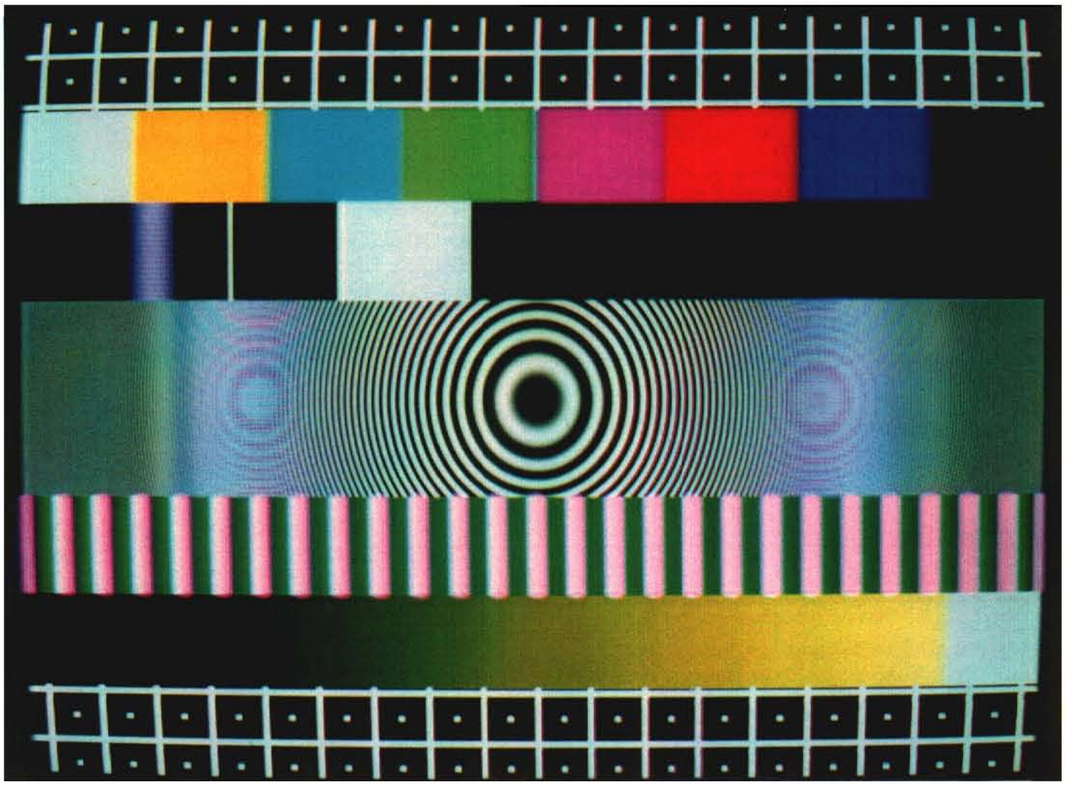
Our own early experiments into electro-mechanical systems showed that the idea of using a steered directional transmitting antenna was reasonably successful but it could only hunt for the *strongest* signal and so could easily lock on to a reflection, or lose lock when momentarily obstructed. As with all electromechanical radio-camera systems, it took no account of the quality of the signal and merely hunted for the strongest direction. Electromechanical systems are also prone to noise, vibration and wear and tear, and are limited by the speed of the motor. However, it has been found that a high degree of steering accuracy is not necessary.

This led to the idea of quantising the possible directions of transmission by using relatively few individual horns, hence the progression to the switched-horn radio-camera.

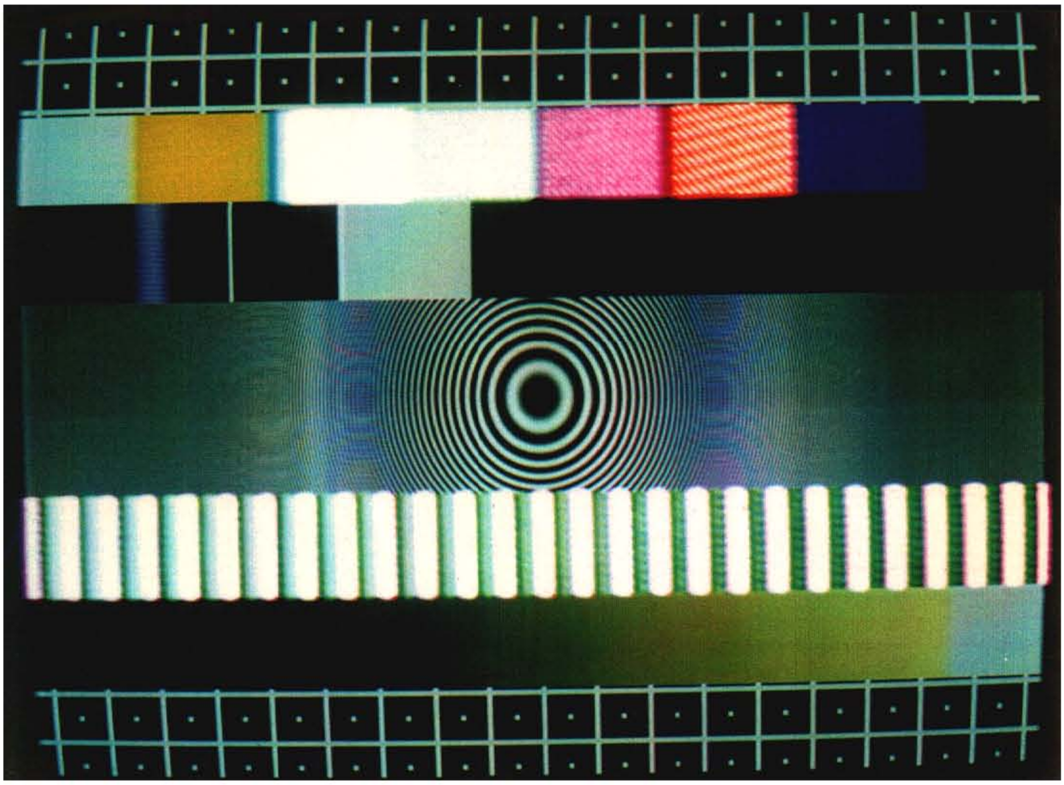
4. THE EFFECT OF MULTIPATH PROPAGATION

Multipath propagation is the effect which occurs when a reflected and therefore delayed signal from the transmitter arrives at the receiver and combines with the signal from the direct path. Certain frequencies will show constructive interference when the direct and reflected signals are in phase, and at other frequencies, when the delay creates a half wavelength phase difference, cancellation results.

An FM radio-camera signal contains a broad range of frequencies over about 20 MHz and so, in the presence of multipath, there may be several frequencies at which cancellation occurs. This gives rise to a comb of notches in the spectrum where the depth of the notches depends on the relative levels of the direct and reflected paths, and the spacing of the notches depends on the delay between them.



(a) Ideal test pattern.



(b) Severe multipath distortion.

Fig. 2 - An example of multipath propagation showing severe colour saturation errors.

The effect of multipath propagation on the picture quality of an FM radio-camera link depends entirely on which part of the spectrum has been affected. The most susceptible part of the video signal is the colour subcarrier, and distortion here shows up as a change in the colour saturation of the picture as can be seen in Fig. 2 *(see previous page)*. Typically, at a sports OB, this will be seen in the grass of the pitch or on the players' shirts.

If the notch lies at the frequency corresponding to the video sync. pulses, then video synchronisation at the receiver can be completely lost. This is often compounded by the frame store synchroniser, which is usually downstream of a radio-camera receiver and which may produce freeze-frame effects or severe colour errors.

5. SYSTEM DESCRIPTION

5.1 Overview

The switched-horn system uses a multi-antenna assembly (or *horn cluster*) with its control box (*camera pack*) at the camera, and a processing base station connected to the receiver, as shown in Fig. 3. The horn cluster mounted above the camera contains six directional horn antennas, all pointing in different directions, but only one horn is used at a time, and this is switched electronically. The most appropriate transmitting antenna is determined by transmitting a test line through each of the antennas in turn (during six of the spare video lines of the field blanking interval) and evaluating them back at the base station. From the results of the test line analysis, the best horn is chosen; this result is relayed back to the camera pack, over a narrowband VHF radio link. The output of the transmitter is then switched to the chosen horn for the next frame. By re-evaluating the transmission paths from each of the horns, and updating the selected horn every frame, the system is able to adapt to the changing position and orientation of the camera.

Because each possible transmission path is assessed every video frame, and the switching is carried out electronically, there are none of the problems of inertia associated with electromechanically steered antennas. Any horn can therefore be selected for any frame, even if it is required to switch instantly from one direction to the opposite. If the path back to the receiver is blocked, the signal may become completely lost, but as soon as the path blockage is removed the switched-horn system will recover within just a couple of frames. The switched-horn system has no hysteresis and so can never 'lock on' to a reflection. Because it uses an electronic switch rather than a motor, it can cope with very fast rotation or panning.

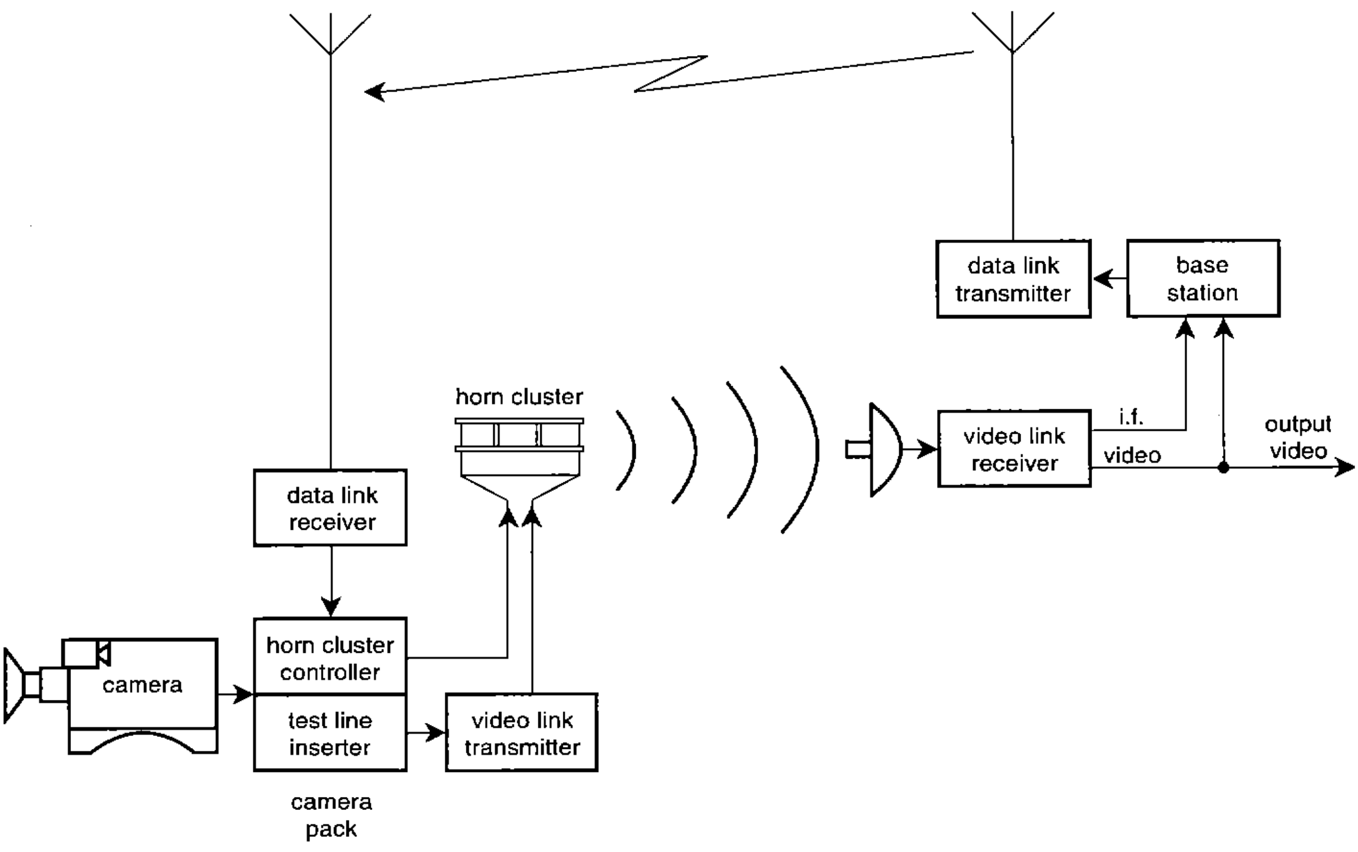


Fig. 3 - The operation of the switched-horn radio-camera.

In practical tests, the system was found to work beyond the speed at which a camera operator could turn. In theory its limit is about 4 revs/second.

The best antenna for a given situation is not necessarily the one pointing directly towards the receiving dish (although this will usually be the case), but rather the one which produces the 'cleanest picture'. The 60° beamwidth of each horn still leaves some possibility of multipath propagation problems, therefore, measuring signal strength alone is insufficient; consequently, a second method of quantifying the transmission path is needed.

Rather than transmitting a blank video-line through each horn during the field blanking interval, a specially designed test-line[1], which is stored inside the camera pack, is used. By assessing the demodulated video from the receiver, each transmission path can be analysed in terms of signal *quality* and not just quantity. The resulting horn selection is based on a combination of the signal level *and* the multipath distortion from each horn. To perform this analysis requires the use of a fast microprocessor running a complex algorithm inside the base station, but the result is an intelligent radio-camera system which provides excellent results.

The switched-horn radio-camera system is unique in its ability to measure the quality of the received signal rather than simply relying on an energy-seeking principle. By using electronic switching, it is able to respond to any changes extremely quickly. Indeed, in order to achieve the response time of the switched-horn system, an equivalent electromechanical system would need to be able to rotate at an impractical rate.

5.2 Camera pack

The camera pack circuitry is housed in a small case attached to the rear of a standard camera and transmitter. Referring to Fig. 4, it takes in video from the camera and adds on the test waveform during the appropriate video lines, before passing the video to the transmitter. At the same time as the test lines are being transmitted, the horn cluster is switched to transmit a line through each horn in turn.

Although the camera pack is small, it contains a large amount of circuitry on two boards as shown in Fig. 5 *(overleaf)*. Virtually all of the digital circuitry is contained in a Programmable Gate Array (PGA) device which is equivalent to about 70 conventional logic devices. VLSI and surface mount components were used extensively in the construction, as compactness and low weight were considered to be prime requirements for use in a practical OB environment.

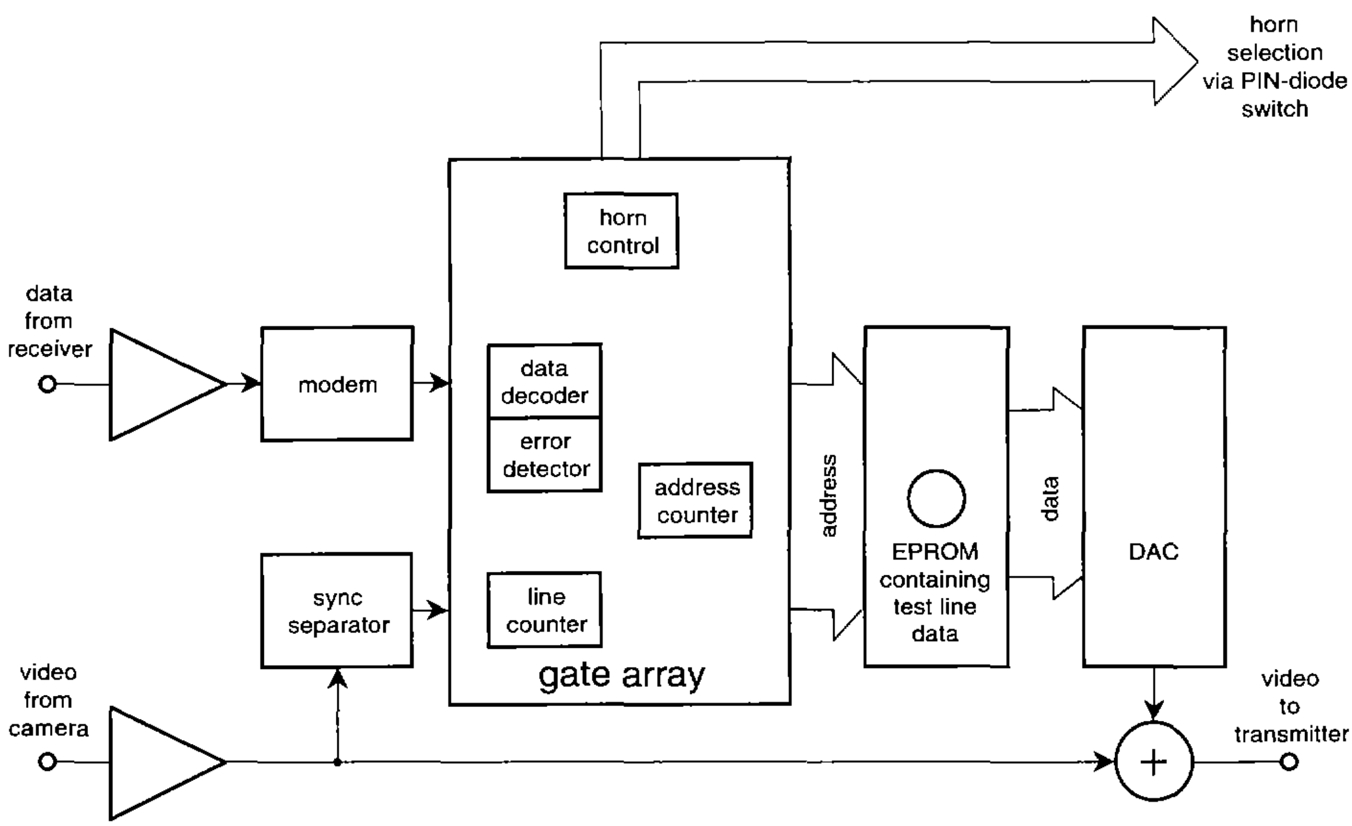


Fig. 4 - Block diagram of the camera pack.

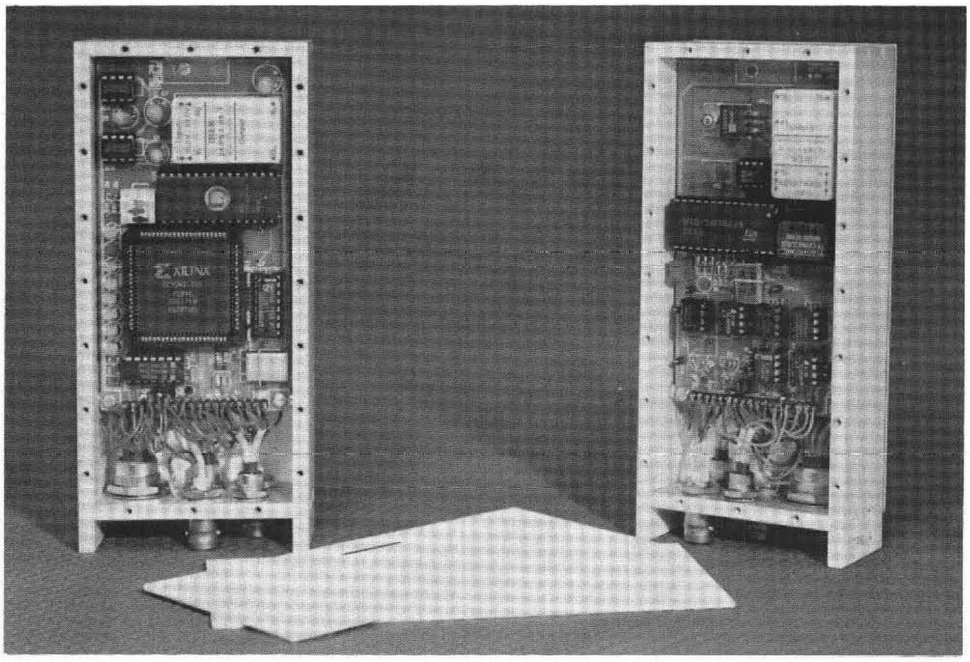


Fig. 5 - The camera pack circuitry — front and rear views of camera pack showing digital and analogue boards.

This compact unit measuring 160 × 70 × 35 mm is shown assembled and mounted in Fig. 1.

5.3 Horn cluster

The horn cluster comprises a cylindrical milled aluminium housing with six vertically polarised horn antennas around the edge, as shown in Fig. 6. Each horn produces a vertical beamwidth of 90° (±45°) and a horizontal beamwidth of 60°, giving complete azimuth coverage. The gain of each horn is about 7 dBi (although this is incidental, as it is the directional property of the horn which is important).

A PIN diode switch is mounted at the centre of the cluster. It is a one input, six output device, and is capable of switching between outputs in about 100 ns, allowing switching between video lines during the test line period. The PIN-diode switch is controlled by the camera pack via a multicore cable.

Fig. 7(a) shows the horizontal radiation pattern obtained from a single horn. The effective combination of all six directional horns gives an approximately

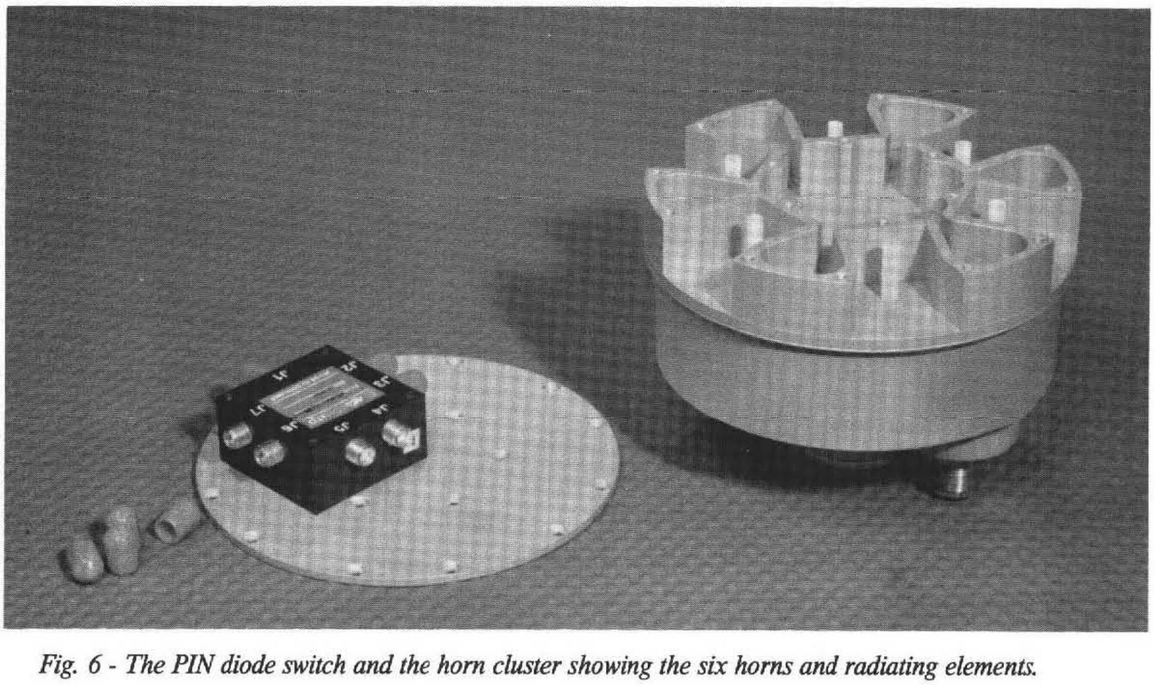
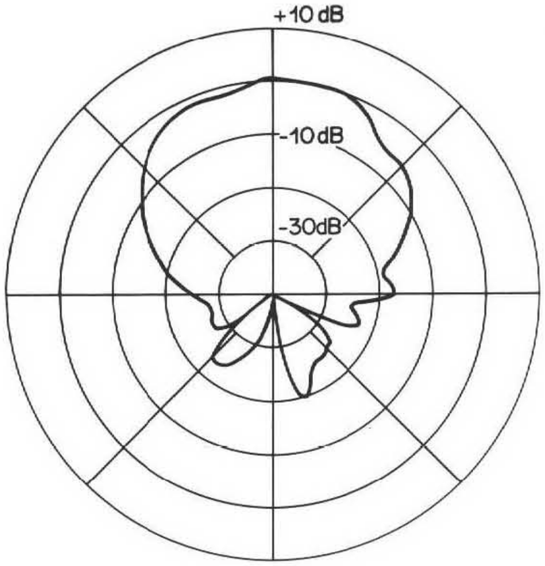
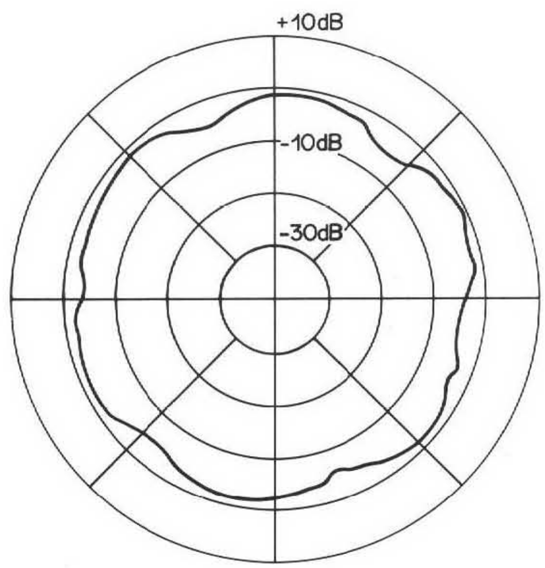


Fig. 6 - The PIN diode switch and the horn cluster showing the six horns and radiating elements.



(a) The horizontal radiation pattern for a single test horn.



(b) The envelope of the horizontal radiation patterns of all six horns.

Fig. 7 - Polar plots.

omnidirectional response as shown in Fig. 7(b), although the contribution from each horn can still be clearly identified.

5.4 Base station

The base station, shown in Fig. 8, is connected to the microwave receiver via feeds of baseband video and intermediate frequency (IF) signals to assess the quality of the transmission. During the field blanking interval, when the six test lines are being transmitted through the six horns, the base station samples the received video signal and the signal strength to assess the characteristics of each of the six possible transmission paths.

The base station functions can be broken down into the following tasks:

1) Synchronise the processing cycle to the video frame cycle.
2) Sample the demodulated video test lines and the RF signal level and store the data in RAM.
3) Quantitatively assess the multipath impairment for each test line.
4) Measure the signal strength for each test line.
5) Combine the multipath and signal level scores to produce a single score for each test line.
6) Compare the final scores for each test line and select the horn corresponding to the test line with the highest score.
7) Encode and then transmit the horn selection data to the camera pack.
8) Handle other interfacing tasks — user switches, display.

The current system runs at 25 decisions per second, where a new 'horn selection' is produced every video frame. In a real-time system such as this, it is important to make the best use of the available time, so the phase of the processing cycle is synchronised to the frame phase of the incoming video signal. This allows the processor to begin analysing the test line samples as soon as they have been captured and then produce a decision in time to be implemented at the start of the next frame.

Apart from the test line analysis, the other time-consuming task is the transmission of the horn selection signal back to the camera pack. The return link carrying the horn selection data uses a VHF talkback channel and so is limited to a bandwidth of 2.3 kHz. This carries a packet of 10 bits of data (2 start bits + 3 actual data bits + error protection) for each decision and takes approximately 8 ms to transmit. The low bandwidth of the link means that

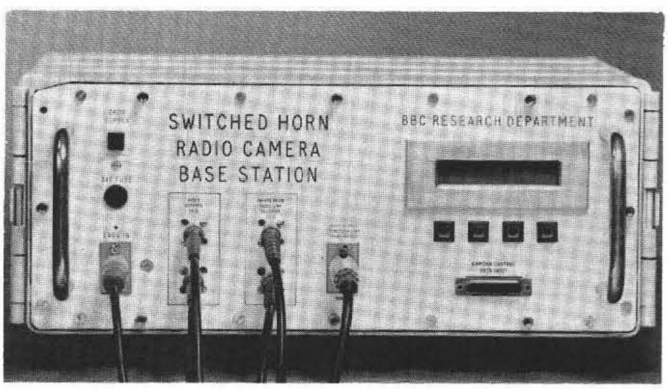


Fig. 8 - The switched-horn radio-camera base station.

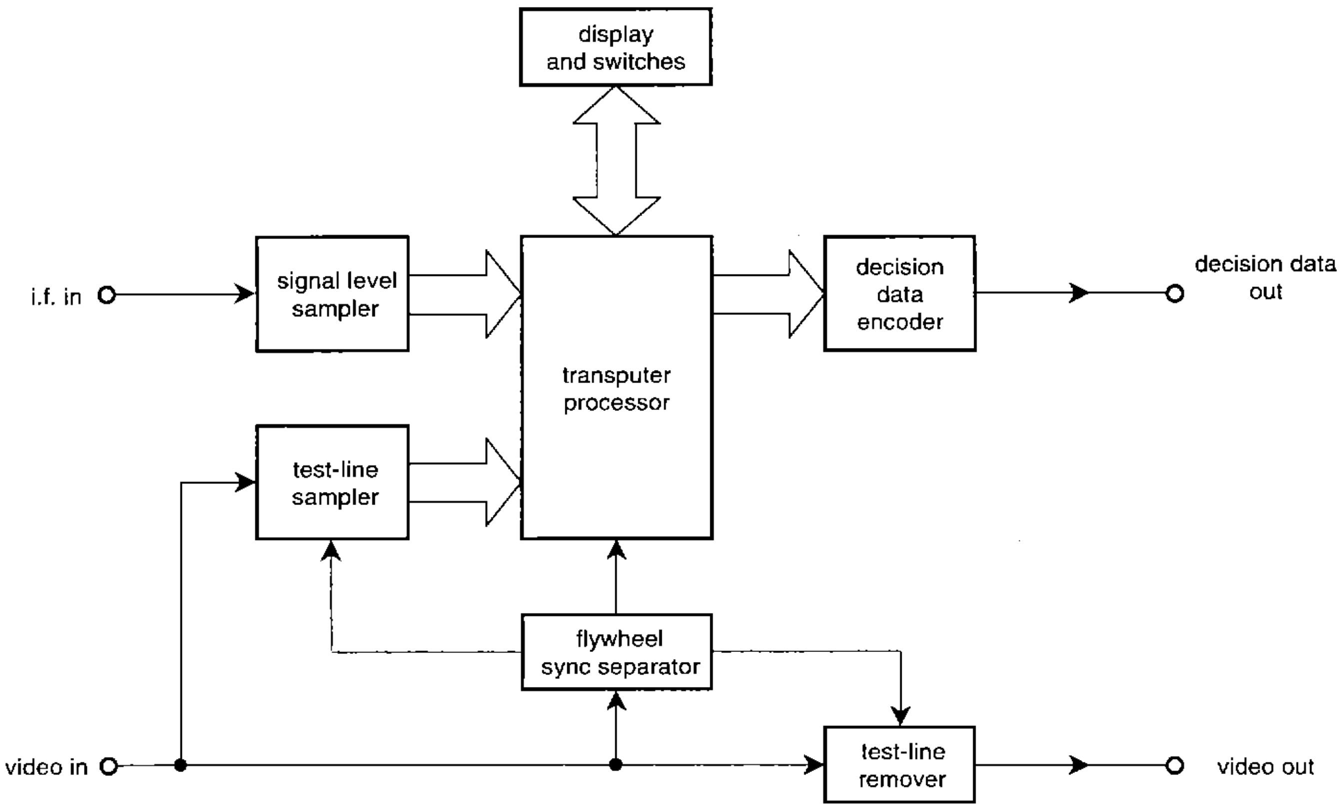


Fig. 9 - Block diagram of the switched-horn base station.

the data packet necessarily takes a significant proportion of the 40 ms. This leaves about 30 ms to analyse six test lines thus giving about 5 ms of processing time per test-line.

In order to achieve the necessary high speed the T800 transputer processor was chosen. The transputer not only runs the multipath algorithm but also generally controls the base station and the interfaces to the outside world, as shown in Fig. 9.

5.5 Sync separator

The signals received from radio-cameras can be variable in quality and it is vital that the base station identifies the correct lines to be sampled even when the video is noisy or momentarily lost (due to an obstruction for instance). A missing line sync pulse or an extra pulse generated spuriously by noise would cause the wrong line to be sampled, which would result in a wrong decision. A 'flywheel' sync separator which is less affected by noise is therefore required. Earlier designs of flywheel sync separator had all suffered from slow lock up, poor noise immunity and frequency decay when flywheeling; so a new design of sync separator[3], based on a gate array, was constructed specifically for the switched-horn system.

The new sync separator is digitally implemented, using a master VCO running at 20 MHz which is divided down using digital counters to give the 15,625 Hz line frequency and also field and frame rates. It performs well with noisy video, has good flywheeling characteristics, and yet has a very fast lock-up time. Its high performance has enabled it to be used in other applications.

5.6 Coding the horn selection data

Towards the end of the video frame, the base station decides on the most suitable horn to use, and this selection is relayed back to the camera pack via a narrow band audio/data transmitter and VHF talk-back receiver. The number to be sent ranges from one to six (for six horns) which requires only three bits, but to improve the reliability of the link, error protection is added.

If the link becomes corrupted due to noise, then the camera pack may possibly misinterpret the data, and select a random horn for the following frame. This horn may well produce a poor quality picture; if it does, the result may be a short flash lasting a frame on the receiver's monitor. Correct operation of the data link is vital to the success of the system, and although 100% error-free operation can never be guaranteed, error protection can greatly improve the reliability of the data link.

There is no scope for data interleaving, as each

selection must be transmitted in sequence and in time for the decision to be implemented at the start of the next frame. The error protection technique employed is, therefore, block coding. Each horn number from one to six is represented by an eight bit symbol using a repeated Hamming code. This code gives six 'legal' symbols out of 256 possible symbols. In this way, most of the erroneous symbols are detected. However, if an error *is* detected by the camera pack, it is *not* corrected as this only compromises the data reliability. Instead, the erroneous data is rejected and the previous successful selection is held. This strategy was chosen because:

a) Data errors are relatively infrequent,

b) The previous frame's horn selection is likely to give at least a reasonable picture, because changes in horn selection are usually between adjacent horns of the cluster, rather than between horns on opposite sides.

5.7 Acquisition strategy

When the switched-horn base station is first switched on, or after a long break in the radio-camera transmission, the sync separator will be out of phase with the received video. The base station cannot reliably select the best horn unless it correctly identifies the position of the appropriate test lines at the start of the frame, and yet it requires a reasonably clean video signal for its sync separator to lock to. This problem originally required some careful consideration and an acquisition strategy was developed.

This acquisition strategy was incorporated into the base station software with a frame being transmitted through each horn in turn to allow the sync separator to lock-up. It was subsequently found that this was not necessary, and that by simply allowing the base station to select a horn in its normal mode of operation, it would choose a good horn within a very few seconds simply by selecting horns at random.

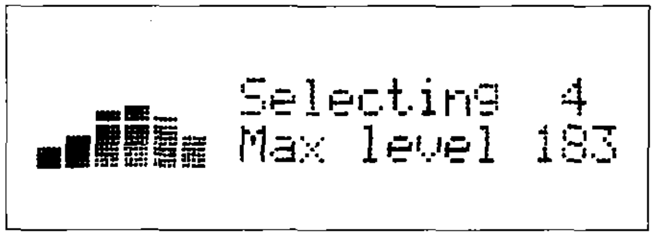
Once reasonable quality video is being received the sync separator could lock up 'more firmly'. This rapid yet automatic acquisition is due to the noise immunity and the short lock-up time of the sync separator.

5.8 System monitoring

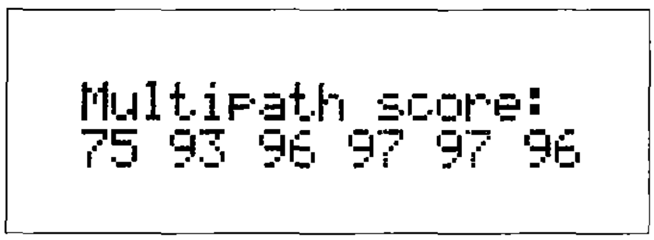
The switched-horn system was developed as a fully automatic system which requires no operator intervention apart from pointing the receiving dish. However, an information display on the base station is used to set up the system. The display has two important modes, enabling it to show the signal level from each horn in bar graph form, and the multipath numeric 'score' for each horn. All the information is updated every frame. The display helps to show up any problems and, with a little experience, can reveal a lot of relevant information.

Fig. 10(a) shows a typical example of the bar graph display. Clearly the strongest signal is being produced by horn number 4, which is facing towards the receiving dish. The lack of signal from horn number 1 which is facing directly away from the receiving dish indicates that the camera is operating in a very open environment.

Fig. 10(b) shows the corresponding multipath score for each horn on a scale of 0 - 99 where 99 represents a perfect picture, and 0 is unwatchable. The score of 75 for horn 1 is a default value given to horns with such a low received signal strength that the calculated multipath score would be meaningless. In an open environment the multipath scores will generally be high, as the reflected paths will be insignificant. Again, the real-time processing allows these results to be updated on a frame by frame basis.



(a) Bar graph showing the signal level received from each horn; the processor's choice of horn (4); and the signal level of the best horn.



(b) The real-time multipath score for each horn.

Fig. 10 - Base station displays.

6. FIELD TRIALS

6.1 Testing at Wembley Stadium

The switched-horn radio-camera system was given an initial field trial in early 1992 at Wembley Stadium, a venue which is renowned for being a difficult radio-camera location with its large amount of structural steelwork. The tests were performed on days when the stadium was not being used allowing the camera operator to move around freely.

For the first test the switching was dependent on signal strength alone, with no multipath analysis being performed, and with simple parity checking on the selection-data link. The system worked largely as anticipated, but with more picture disturbances than would have been expected using a directional transmitting antenna. This was attributed to occasional data link failures; so the error protection was increased to the present 10 bit system. This resulted in a marked improvement for the second test.

A third test was conducted in December 1992 to evaluate the effect of the new multipath analysis software. The basic system which measures signal strength alone was compared with the combined *multipath and signal strength* assessing version.

The results of the recordings of the test showed that both versions of the switched-horn system produced good results when a line of sight path back to the dish was available, and that the version which assessed multipath *and* signal strength performed even better, producing just two poor frames during a seven minute tour around the edge of the pitch. The performance was much less affected by nearby reflecting surfaces, such as the crowd control fencing which surrounds the pitch at Wembley Stadium. The dish operator commented that the signal strength meter on the receiver was much more consistent with the switched-horn system than with omni-CP antennas.

6.2 Live programme test at Murrayfield

In February 1993, Television Outside Broadcasts, Scotland, requested the switched-horn radio-camera to overcome the particularly difficult multipath problems experienced when operating in the Murrayfield stadium with conventional 2.5 GHz omni-directional CP radio-cameras. Normally, for live coverage of the Scotland-Wales rugby match two 2.5 GHz omni-CP radio-cameras would be used, but for this match one of them was to be replaced with the switched-horn system. Fig. 11 shows the two cameras operating on the touch-line at Murrayfield.

Extra equipment was borrowed from Television Outside Broadcasts, London, to make up a full system that was largely independent of the rest of the outside broadcast facilities.

Fig. 11 - The switched-horn radio-camera (arrowed) being used live on-air alongside a conventional omni-CP radio-camera at Murrayfield in February 1993.

The switched-horn camera gave some excellent shots of the teams being presented to Princess Anne and some exciting shots of the line-outs and scrums during the match itself. By reviewing the recording it was found that the switched-horn camera was used for a good proportion of the time during the live match itself; and during the recorded highlights, 'Rugby Special', shown the following day, the shots from the switched-horn camera were even more popular compared with those from the other radio-camera. Generally, the switched-horn camera was used twice as often as the 2.5 GHz omni-CP.

Close examination of the recorded programme revealed no evidence of multipath distortion. In particular, the bright colours of the rugby players' shirts, which are often a problem with radio-cameras, showed a constant saturation. The trial has shown that the switched-horn concept is a most effective method of combating the multipath problems normally associated with hand-held radio-cameras at OB events.

7. RELATED WORK — DIVERSITY RECEPTION

There are two main causes of radio-camera link failure. One reason is multipath propagation caused by reflections from surrounding surfaces, including the ground. The other reason is the loss of line of sight path due to blocking, either by a structural obstacle such as a wall, or a temporary obstacle such as a person — including the camera operator himself. Both of these problems can be greatly reduced by providing a second receiving site and introducing an extra receiver to provide an alternative source of video.

A base station connected to the receivers' outputs analyses the incoming video signals and the received power levels, and selects the video from the receiver which is providing the best picture. As with the switched-horn system, this comparison is performed every frame and so can react quickly to any changes in the transmission paths, whether these are caused by path blocking or multipath distortion.

The receiver diversity system contains many features in common with the switched-horn system. A companion Report[4] will give more details.

8. RECOMMENDED FURTHER DEVELOPMENTS

The switched-horn radio-camera system has reached the stage where it can be developed into a commercial product and indeed the system has been licensed to a manufacturer. It is, however, possible to improve the basic system described to provide extra features, to make the system easier to use operationally, and to improve the performance even further.

The prototype antenna is rather heavy, having been milled from aluminium. Reducing the weight of the antenna is very important because of its high position. Much excess material could be removed while maintaining the necessary performance and strength of the antenna. Other options include making the antenna from metallised plastic, or using printed *circuit patch antennas*.

The prototype antenna emits a linearly polarised signal. There is a theoretical advantage in that it might be possible for the system to use a signal from a 'clean' reflection under circumstances where the direct path is blocked (e.g. if the cameraman walks behind a pillar). The disadvantage is that there is still the possibility that reflections may occur within each horn's 60° beamwidth (e.g. the ground reflection) and these may still produce multipath distortion. Such multipath could be minimised by using a circularly polarised antenna but this would prevent the use of clean reflections when the direct path becomes obstructed. Operational experience will tell if this is needed. It is a simple matter to interchange the antenna head assembly if required.

In some circumstances, reverse video to the cameraman is required. This would probably require a second horn cluster on the camera mast because the isolation that can be obtained with a circulator and filters would not be sufficient within the allocated frequency bands. This puts even more emphasis on the use of lightweight materials. In principle, the return bearer can be used to carry other signals such as talkback and racking (the control of camera functions such as iris, and colour balance). However, the horn selection data would be more suited to a lower frequency RF link such as the existing VHF link which does not require a line of sight path to be maintained.

Radio-cameras are usually equipped with a microphone to pick up effects audio or speech in an interview. This audio is usually carried on an FM subcarrier above the video, typically around 7 MHz. Unlike video, however, sound is continuous and a disturbance is caused during the field blanking interval when the test lines are being transmitted through the six horns. The horns which are pointing away from the receiver will produce such a weak signal that a momentary burst of noise is caused, as either the main carrier or the sound subcarrier is lost. The audible effect of this is to produce a series of clicks on the audio channel at a similar level to the wanted sound.

There are several potential ways to eliminate such interference, and it is recommended that this problem is studied further.

In the longer term there is likely to be a need to move to digital techniques, widescreen and high definition signal formats. The increased bandwidth required to maintain studio-quality signals suggests a move towards higher frequency operation (e.g. the 60 GHz band). Research Department has, therefore, become part of a European Community research project called RACE Mobile Broadband Systems (R2067) which aims to develop a radio broadband network at about 60 GHz for a wide range of commercial applications.

These digital solutions would of course require all the camera mounted components to be as compact and lightweight as their current analogue counterparts, and so portable digital radio-cameras are still a long way off. Multipath-proof radio-cameras would, however, find instant application in studios.

9. CONCLUSIONS

A switched-horn radio-camera system has been described which achieves directional transmission of FM video signals in the 12 GHz band from a single operator camera to a receiving station. There are no moving parts in the antenna attached to the camera. The beam is directed by electronically selecting one of an array of six horns in the antenna. Test signals inserted into the video field blanking interval are analysed at the receiving base station to determine which horn will provide the best signal. Both the received signal power and degree of multipath are analysed to determine which is the best horn. The choice of horn is updated every video frame, enabling the switched-horn system to adapt to the changing orientation and environment of a moving camera.

Although this development was aimed at the 12 GHz band, there is no reason why it should not be applied in other radio-camera link bands, subject to physical constraints on the antenna size for the lowest usable frequencies.

Unlike all other 'tracking' radio-cameras the switched-horn system considers both the quality and quantity of the received signal. This, and its speed of operation, makes it by far the most sophisticated radio-camera system yet devised, and should provide a useful facility for many years to come. The extra cost of the system, which is comparable to that of electromechanical systems, is a small price to pay for a highly reliable source of OB pictures.

Two field trials have been described, one of which was during a live programme transmission. The results of the trials showed that the switched-horn system is much less affected by multipath distortion than systems using omnidirectional antennas, and does not have any of the side effects of electromechanical systems.

Radio-cameras are already an important tool for broadcasters and the commercial exploitation of the switched-horn system will allow radio-cameras to be used even more widely in future.

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